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# SAFETY TESTS OF EXPLOSIVES TRANSPORT TRUCKS

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by

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ABSTRACT. Five safety tests were conducted on 1/2- and 3/4-ton pickup trucks of the type used to haul explosives aboard the Naval Weapons Center. The tests were designed to determine the effectiveness of the steel flash shield between the truck cab and bed in shielding personnel in the cab against the hazards resulting from inadvertent initiation of explosives materials being transported. For each test, the explosives material, the method of initiation, test instrumentation, and a discussion of the results are given. The limitations of the shield and suggestions for improved safety protection for truck personnel are included.



## NAVAL WEAPONS CENTER

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### FOREWORD

This report summarizes the results of five tests conducted at the Naval Weapons Center to study the effectiveness of flash shields placed between the cab and the bed of pickup trucks of the type used for hauling explosives at NWC.

The work covered by this report was funded by Safety Department overhead funds and by Propulsion Development Department safety overhead funds. The work was carried out during the period from June to October 1967.

This report was given technical review by Jack Sherman of the Propulsion Development Department and Thomas Boyd of the Public Works Department.

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## INTRODUCTION

Explosives, propellants, and other hazardous materials are regularly transported aboard the Naval Weapons Center in trucks modified to provide added protection to personnel hauling such materials. The modification has generally consisted of a protective flash shield constructed of 1/4-inch-thick steel plate and placed between the cab and the truck bed. Before the tests reported here, the effectiveness of this shield had not been tested, and there was no realistic measure of the protection it might provide in the event of the accidental initiation of explosives materials being transported.

To determine, at least qualitatively, the amount of protection the shield would give, a series of five tests (Table 1) was conducted. Various amounts of several materials placed in trucks under conditions that occur daily in transporting explosives materials aboard the Center were ignited or detonated, and the results were assessed.

TABLE 1. Safety Tests of Explosives Transport Trucks.

Test no.	Test type	Hazardous material	Material weight, lb
1	Burning	Double-base and fluorocarbon bulk propellants	600
2	Burning	Pyrotechnic flare	50
3	Detonation	Composition C-3	2
4	Detonation	Composition C-3 HE fragmentation warhead	10
5	Detonation	PBXC-104 HE fragmentation warhead	50

## SAFETY TESTS OF EXPLOSIVES TRUCKS

Test firings were conducted in accordance with the general operating procedure for the test area. All personnel were located inside the control building during the firings and remained in the building until the area was cleared by the test conductor. The firings and all cameras were actuated at the control panel. The tests were observed by means of two closed-circuit TV monitors.

## TEST SETUP AND INSTRUMENTATION

Five "surveyed" trucks obtained from the Public Works Department and fitted with beds and shields as required for all NWC explosives hauling vehicles were placed in a semicircular array in one of NWC's explosives testing areas.

All tests were made using 1/2-ton pickup trucks, except Test 4, in which a 3/4-ton truck was used. All trucks had gasoline in the tanks except the truck in Test 3, from which the gas tank had been removed. Between the cab and the bed each truck had a 1/4-inch-thick steel shield that extended the full height of the cab. The shield was 4 feet wide for Tests 1, 3, and 4, and 4 1/2 feet wide for Tests 2 and 5.

On the day before the tests were to be run, mannequins dressed in coveralls, safety glasses, and hard hats were placed in the driver's seat of four of the trucks, and an anthropomorphic dummy was placed in the other truck (for Test 5). Thermocouples were installed in the truck cabs for the two burning tests, and pressure transducers were placed in the truck cab for the 2-pound detonation test.

Still and motion photographs in black and white and color were made before, during, and after the tests. For all tests, camera coverage at 24, 64, and 400 frames per second was provided; Tests 3, 4, and 5 were also photographed at 4,000 and 8,000 frames per second; a Hulcher camera recorded Tests 1 and 2 at 20 frames per second and Tests 3, 4, and 5 at 70 frames per second.

### TEST 1

For this test of the hazards of burning propellant to a truck and its occupants, 600 pounds of bulk double-base and fluorocarbon propellants in wooden boxes with lids were placed at random on a truck bed and ignited (Fig. 1 and 2).



FIG. 1. Typical 1/2-Ton Truck Used in Explosives Safety Tests.



FIG. 2. Boxed Bulk Propellant Loaded on Truck Bed for Burning, Test 1.

### Method of Ignition

The fluorocarbon propellant was ignited by means of two spirals of Quick Match attached to two Electric Matches and embedded in the propellant.

The double-base 1- by 30-inch propellant rods were wrapped, two rods together, with 10 wraps of Quick Match connected to two Electric Matches. The rods were put in two boxes and placed on the truck bed.



## Instrumentation

To measure temperature, three thermocouples were installed inside the cab of the truck: one on the seat beside the mannequin, one taped to the face of the mannequin, and one taped to the hand of the mannequin.

## Results

After propellant ignition, burning continued for 2 to 3 seconds, after which time an explosion or low-order detonation occurred. Propellant was scattered over a wide area, up to 298 feet from the truck. Much of the propellant did not burn. The bed of the truck was destroyed, pieces of it being thrown as far as 234 feet. The steel shield was blown against the back of the cab and then slid down onto the bed of the truck (Fig. 3). Figure 4 shows that the inside of the cab was completely gutted by fire and that the mannequin was destroyed. The thermocouple attached to the face of the mannequin indicated a temperature rise to  $520^{\circ}\text{F}$  in 4 seconds and then failed mechanically. The thermocouple attached to the hand recorded nearly as rapid a rise to  $300^{\circ}\text{F}$ , a slight dip, and then a rise to  $410^{\circ}\text{F}$  about 10 seconds after the start of the test. The thermocouple on the seat beside the mannequin reached  $130^{\circ}\text{F}$  in 4 seconds and then decayed slowly.

The right rear wheel of the truck was blown off; the left rear wheel burned on the truck; but the front wheels and tires were not damaged. There was little evidence of fire in the engine compartment or front of the truck even though the hood was blown open by the blast.



FIG. 3. Truck Damage From Burning and Subsequent Explosion of 600 Pounds of Propellant, Test 1.





FIG. 4. Destruction of Mannequin and Cab Interior, Test 1.

### Discussion

It is doubtful that persons in the cab could have escaped without rather severe burns. Since only a burning test was desired, there was no measurement of blast pressure. This test, however, gave good evidence that we cannot expect hazardous materials to react in accordance with our plans. The unplanned reaction was due either to too strong ignition or too great confinement of the propellant.

## TEST 2

Test 2 was a burning test of 50 pounds of pyrotechnic material, that is, one Briteye flare candle in a wooden box placed near the rear of the truck bed in the normal hauling location (Fig. 5).

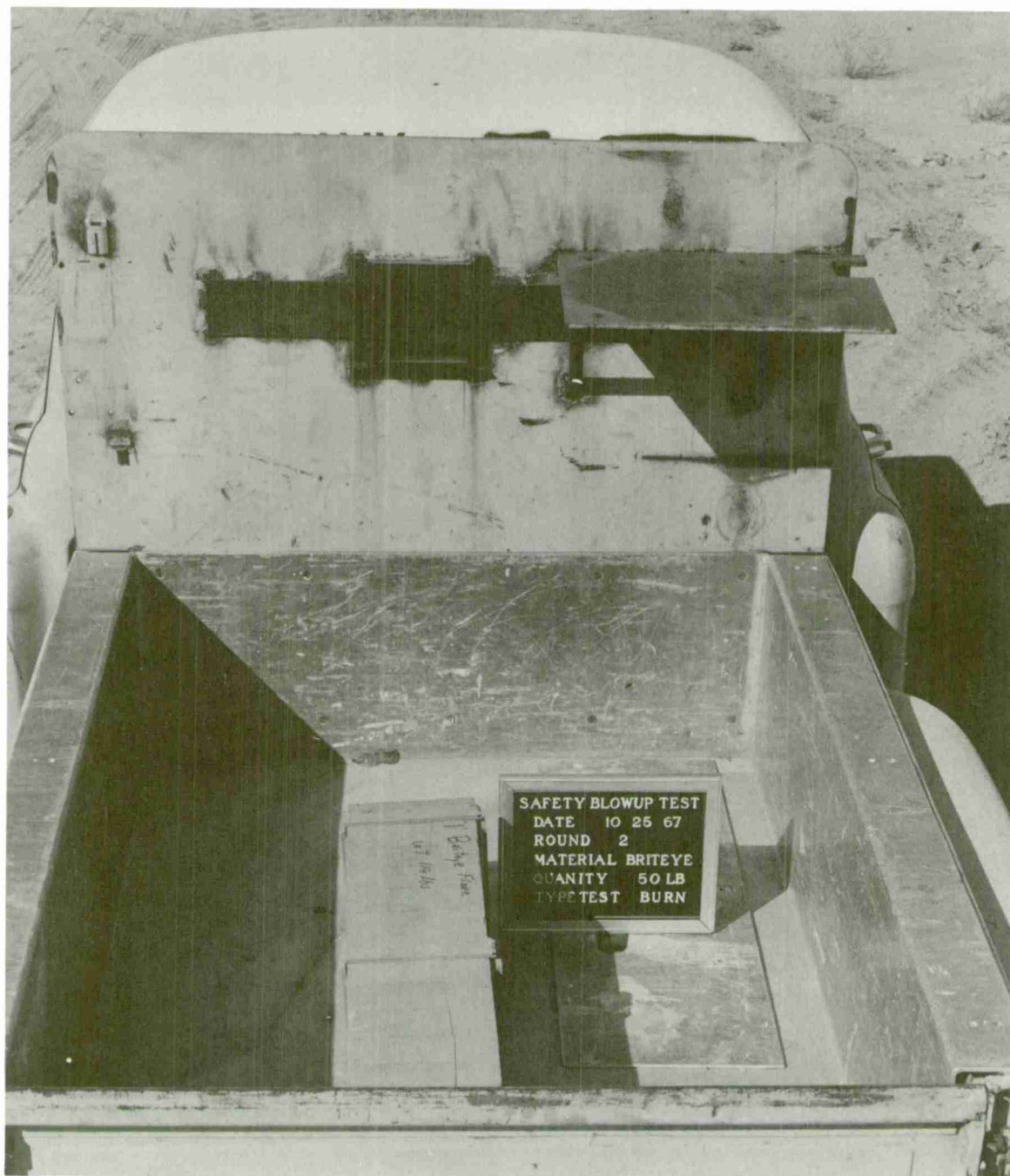


FIG. 5. Truck Loaded With 50-Pound Flare for Test 2.

## Method of Ignition

The flare was ignited by four large spirals of Quick Match attached to four Electric Matches and taped to the face of the flare.

## Instrumentation

The instrumentation setup for this test was the same as for Test 1. A mannequin was placed in the cab, with thermocouples taped to the hand and the face. A third thermocouple was taped to the seat beside the mannequin.

## Results

The flare burned for about 5 minutes. It burned through the aluminum truck bed, but there was little evidence of the burning of any other materials (Fig. 6 and 7). The steel shield appeared to be undamaged. The truck was observed on the TV monitors for about 15 minutes after the flare stopped burning, and, since there was no further evidence of burning, all test personnel left the area for lunch. A short time later (estimated to be less than 15 minutes), the residual heat again ignited combustible materials of the truck, including the cab interior, engine compartment, and tires. The truck had completely burned when personnel returned to the area about 1 1/2 hours later (Fig. 8). The three thermocouples in the cab did not show any temperature rise during the time the flare was burning.



FIG. 6. Truck After Burning, Test 2.



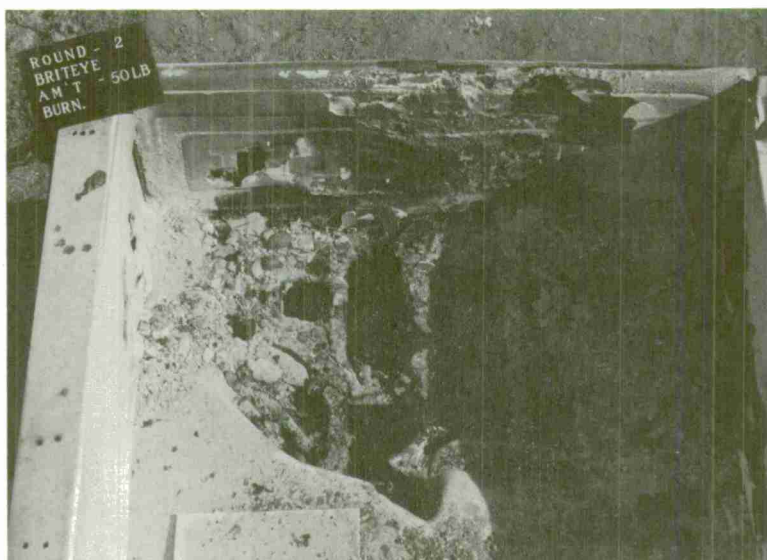


FIG. 7. Damage to Truck Bed, Test 2.



FIG. 8. Destruction Resulting From Reignition Caused by Residual Heat of Combustible Material, Test 2.

## Discussion

With the existing test conditions, it is certain that personnel could have safely left the cab without suffering any severe burns. If the flare had been located near the front of the truck bed, however, the possibility of receiving burns would have been greatly increased.

## TEST 3

Test 3 was a detonation test in which a 2-pound demolition block of Composition C-3 in a wooden box was placed on the bed of the truck just behind the driver (Fig. 9).



FIG. 9. Truck Bed With 2-Pound Block of Composition C-3 in Place for Test 3.

## Method of Initiation

One Engineers Special blasting cap was used to initiate the detonation.

## Instrumentation

Three pressure transducers were installed in the cab, one on the back of the seat behind the driver, one on the seat beside the driver, and one on the dashboard in front of the steering wheel.

## Results

Detonation was high order and complete. The whole left side of the truck bed was torn loose and peeled back from the bed (Fig. 10). The rear of the right side was pulled back to the fender area. The tail gate was torn loose and blown back 68 feet beyond the rear of the truck. Other pieces of the truck metal were blown as far as 70 feet from the truck. The lower corner of the steel shield was pushed into the cab below the driver's seat with sufficient energy to tear a hole in the metal of the cab (Fig. 11). Figure 11 also shows that the welded aluminum bed was torn and pulled back at the front corners. A 32-in<sup>2</sup> hole was blown through the bed of the truck in the place where the Composition C-3 block had been.

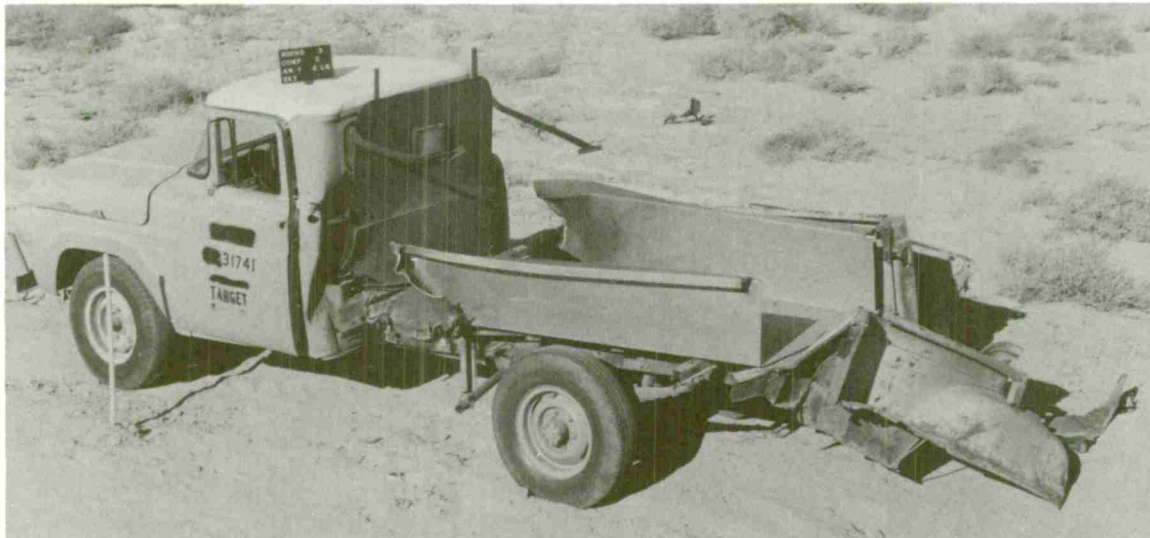


FIG. 10. View of Truck After Detonation, Test 3.





FIG. 11. Closeup of Damage Resulting From Test 3.

Although the pressure transducers did not show any rise in pressure, there was evidence of pressure rise within the cab. Figure 12 shows the window in the rear of the cab pushed outward and severely cracked. It was still in place but was torn loose from the bottom mounting. The windshield was cracked, and the frame was pulled loose. The mannequin had been thrown against the steering column, and the hard hat had been torn loose from the headband that was still on the mannequin. The roof of the cab showed evidence of being pushed up slightly and had buckled at the right front corner.



FIG. 12. Mannequin and Cracked Rear Window of Cab, Test 3.

## Discussion

There is no doubt that personnel in the cab would have sustained some injury caused by displacement in position. Although the transducer showed no pressure, there was indication of pressure in the cab that might have caused ear damage or at least discomfort.

## TEST 4

For Test 4, a detonation test, a wooden box containing a Sidewinder high explosives (HE) fragmentation warhead loaded with 10 pounds of Composition C-3 was put in place near the rear of the truck bed (Fig. 13).

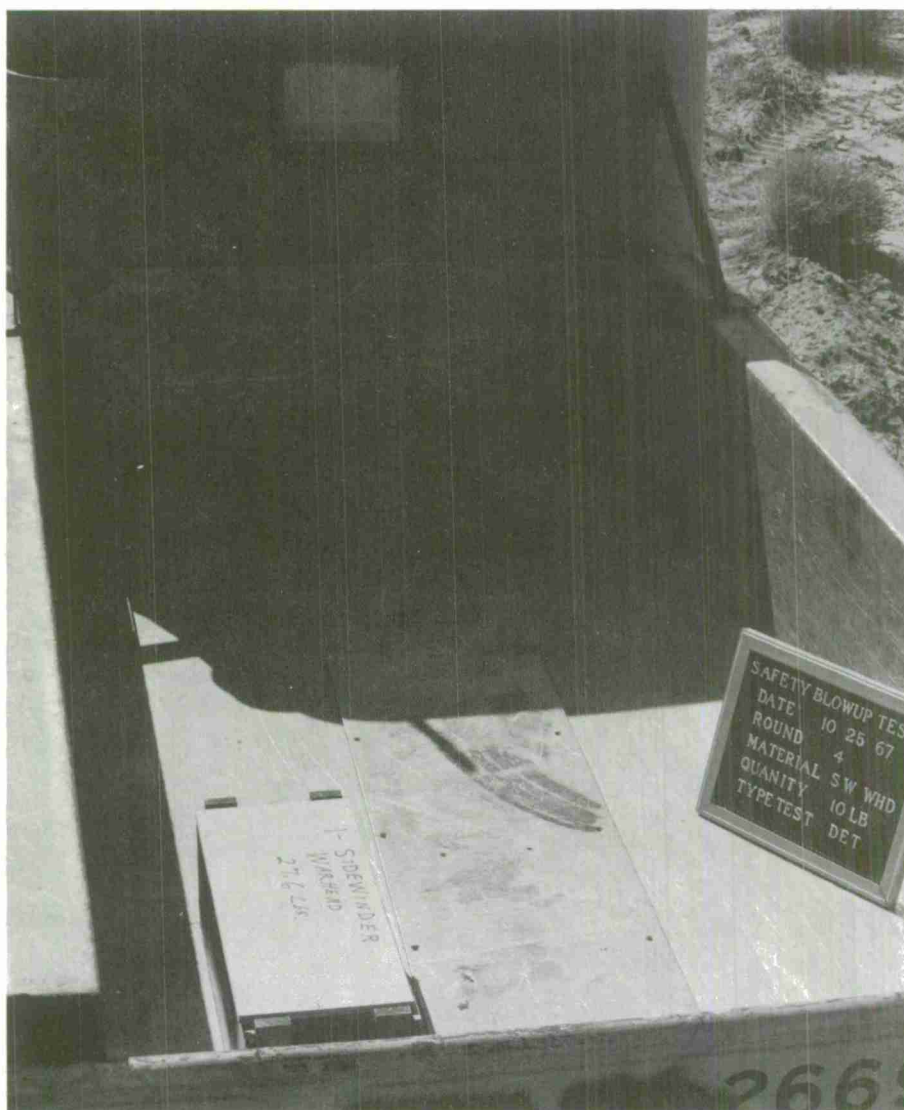


FIG. 13. Fragmentation Warhead in Truck for Test 4.

## Method of Initiation

Initiation was by means of a 0.75- by 0.75-inch tetryl booster and an Engineers Special blasting cap.

## Instrumentation

None.

## Results

The truck bed was completely blown from the truck, and both rear wheels and tires were severely damaged. The steel barrier shield was torn loose and pushed into the back of the truck cab, forcing the mannequin against the steering column with sufficient force to break the steering column (Fig. 14 and 15). The back of the seat was blown partially through the windshield, which was almost completely blown out. The cap was blown off the gas tank, and the tank was punctured near the top. There was also evidence that some gas had spilled out and burned on the ground beside the truck. No other evidence of burning was apparent in this test. The hood of the truck was blown off. Pieces of the truck metal were blown to a distance of 262 feet from the truck (Fig. 16).



FIG. 14. Damage Resulting From Detonation, Test 4.





FIG. 15. Cab of Truck After Test 4.



FIG. 16. Dispersion of Truck Fragments (Arrows), Test 4.

## Discussion

By the extent of the damage resulting from the detonation, there is little doubt that persons in the truck cab would have been fatally injured.

## TEST 5

For Test 5, a detonation test, a Shrike fragmentation warhead loaded with 50 pounds of PBXC-104 and placed in a wooden box was located near the rear of the truck bed (Fig. 17).

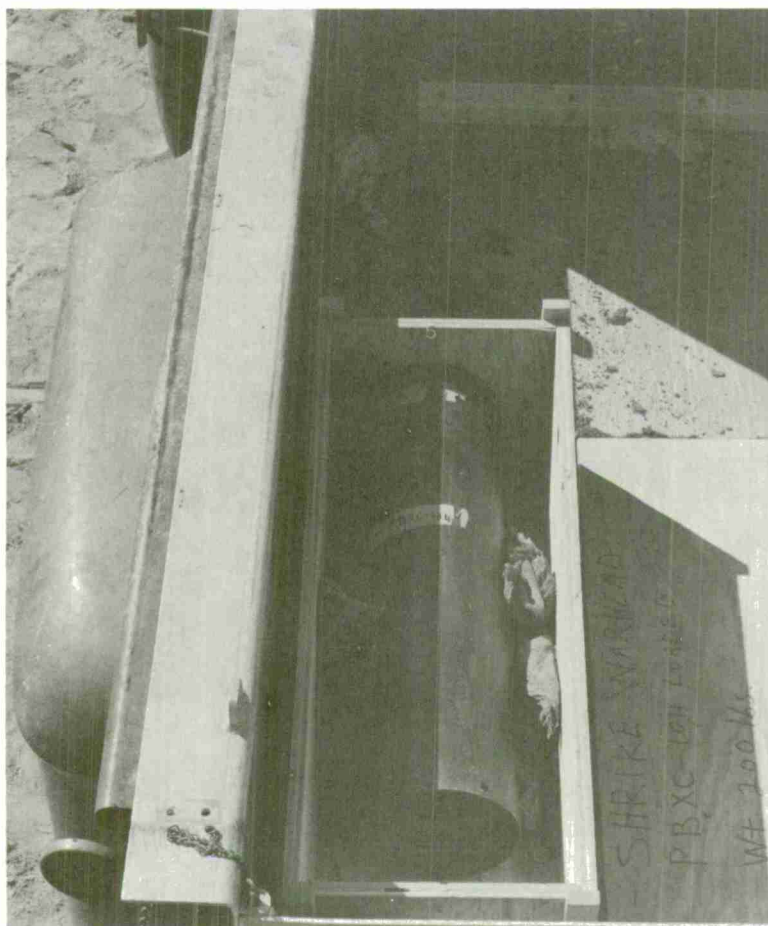


FIG. 17. Truck Loaded for Test 5.



### Method of Initiation

A 1- by 1-inch tetryl booster and an Engineers Special blasting cap were used to initiate the detonation.

### Instrumentation

None.

### Results

All of the truck aft of the cab was completely blown apart (Fig. 18), and pieces were blown to a distance of 681 feet from the test location. The remainder of the truck and the anthropomorphic dummy used in this test were completely burned by the fire resulting from the blast (Fig. 19).



FIG. 18. Condition of Truck After Detonation of 50 Pounds of PBXC-104 Explosive, Test 5.

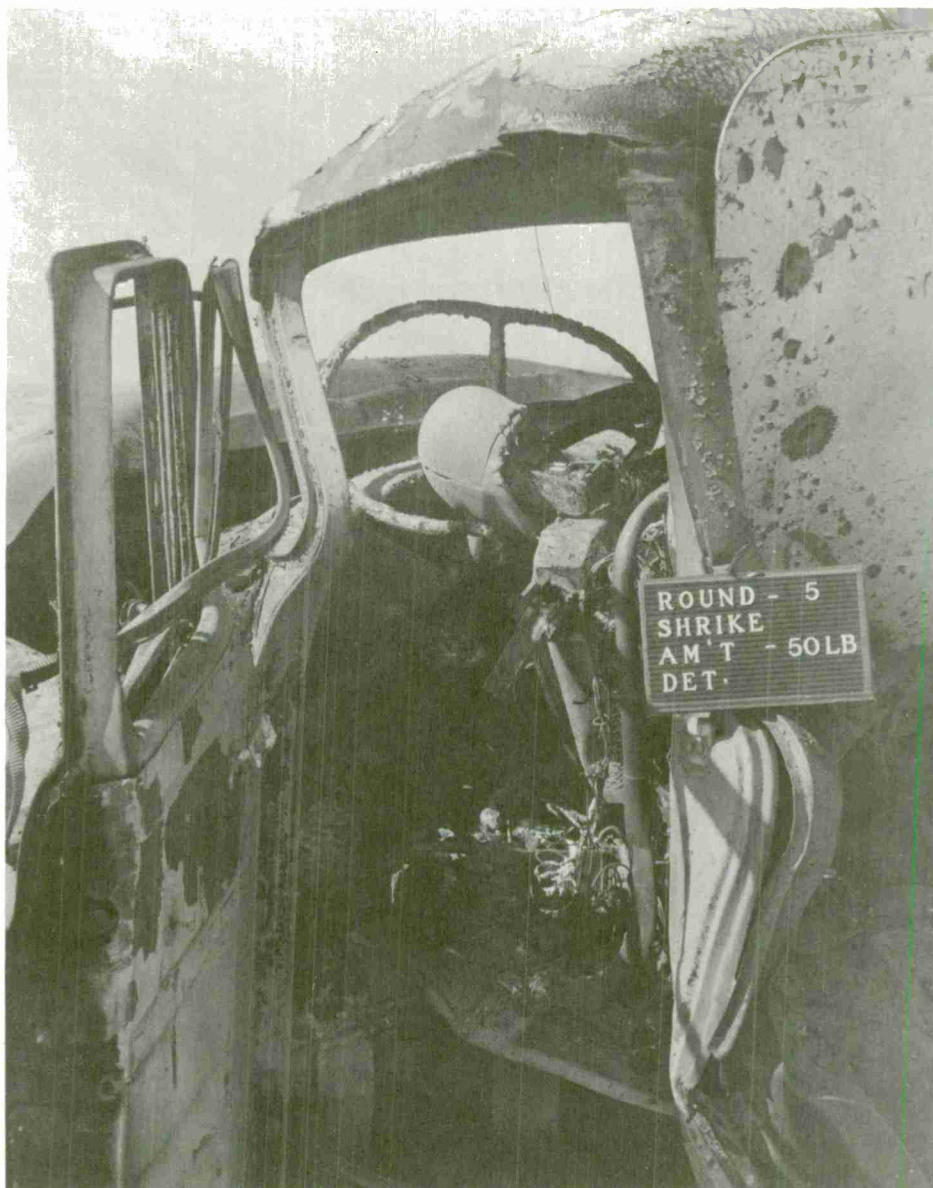


FIG. 19. Damage to Cab and Dummy, Test 5.

## Discussion

Personnel in or adjacent to the truck would have been fatally injured.

## CONCLUSIONS AND RECOMMENDATIONS

This report describes a series of tests made to indicate the hazards to personnel in the cab of explosives transport trucks should they be exposed to burning materials or explosives detonation in the truck bed. Observation of damage to the trucks and to mannequins in the truck cabs as the result of burning and detonation tests indicates the following:

1. The steel shield between truck bed and cab offers some protection against burning material in the back of the truck and provides additional time for personnel to leave the truck in an emergency.
2. The shield does not protect against damage from large amounts of material, but does offer some protection in the case of detonation of small amounts of explosives in the truck.

To reduce the hazards to personnel in the trucks, the following recommendations are made.

1. Whenever possible, the explosives material being hauled should be located toward the rear of the truck bed, away from the cab.
2. When the results of ignition are directional, the items should be oriented in the truck bed to reduce exposure to persons in or leaving the truck cab.
3. A shield of greater width than the steel shield tested would probably provide some increased protection against larger fires. The width of the shield should be limited to a width that would not create a hazard to normal driving.
4. Cab windows should be kept closed to provide additional protection from the initial flash and from flames curling around the shield and the cab.
5. Cab doors designed to open toward the front of the truck would provide additional protection for personnel during exit from the cab.
6. The addition of wing panels on each side of the shield extending toward the rear of the truck bed would help to deflect flames away from cab doors.
7. Additional tests should be made to determine amounts of explosives for which the shields will offer protection. Other parameters such as the wing panels mentioned in item 6 above should be tested.

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